REMARKS

This amendment is responsive to the Office Action of September 18, 2009. Reexamination and reconsideration of the application are respectfully requested.

The Office Action

The **Drawings** stand objected to under 37 CFR §1.83(a).

Claims 18–20 were stated as being directed to a non-elected invention.

The amendment filed March 16, 2009 stands objected to under 35 USC §132(a) as introducing new matter into the disclosure.

Claims 1–10 and 13–16 stand rejected under 35 USC §102(e) as being anticipated by Slatkine (US Patent No. 7,184,614; US Pat. Appln. Publn. No. 2004/0036975; or WO 2003/049633).

Claims 11 and 17 stand rejected under 35 USC §103(a) as being unpatentable over Slatkine and Muller.

Citation of Muller Reference

The Muller reference was used in the rejection of **claims 11 and 17**. However, the Muller reference not been listed on either a PTO/SB/08 form (submitted by the Applicant with an Information Disclosure Statement) or a PTO–892 form provided by the Examiner. Since the Examiner has used the Muller reference in a rejection, Applicants request that the Examiner issue a PTO–892 form citing the Muller reference.

Drawings

FIGURES 1 and 2 have been amended to mark the illustrated elements with indicia indicative of their respective functions. Therefore, the objection to the drawings has been overcome.

35 USC §132

In the Office Action, the Examiner stated the "apparent source size of 6 mm^2" (see claim 17) is not supported by the originally filed application. However, Applicant points to the last paragraph on page 6 of the application, which states "the apparent aperture of the source laser device is made uniformly larger to the order of 6 mm^2." As discussed during the telephone interview of December 10, 2009, **claim 17** has been amended to recite an apparent source size of about 6 mm^2.

The Examiner also stated the "apparent source size of said laser beam is greater than that required as a minimum condition for classification of said device as a Class II laser" is not supported by the originally filed application. Applicant points to the first paragraph on page 5 of the application as originally filed. That paragraph states "[s]uch devices are usually class IIIB but by using the invention described herein will become Class 1." Therefore, the application as originally filed contemplates changing from a class III to class I laser. Class II lasers are inherently included in the range between class III and class I lasers. Therefore, Applicant submits that the statement "apparent source size of said laser beam is greater than that required as a minimum condition for classification of said device as a Class II laser" is supported by the originally filed application.

The attached discussion of laser classification is provided from http://en.wikipedia.org/wiki/Laser_safety.

Several laser parameters allow one to define the safety classification and includes power, wavelength, etc. AND the ability of the eye to focus the light to a small spot on the retina. For example, if similar forces are applied to both a pinpoint and a dime against the skin, the pinpoint is more likely to pierce the skin and cause pain. The ability to focus to a small spot size is also determined by several parameters but one of the key parameters is the apparent aperture of the source. The bigger the apparent aperture, the bigger the minimum focused spot on the retina. The laser diode has an output aperture on the order of a few microns, so theoretically the light exiting the output aperture may be focused to that sort of size on the retina. By using a diffusing element, the aperture may be increased to about 6 mm^2. Hence, the minimum size of the focused spot on the retina is increased and the possibility of damage is substantially decreased.

The Claims of the Present Application Are Patentable Over the Cited References

Applicant thanks the Examiner for the telephone interview granted with Applicant's attorney, Brian Kondas, on December 10, 2009. During the telephone interview, the Examiner agreed that Slatkine is not prior art against the claims of the present application. Therefore, **claims 1 and 14 and claims 2–11, 13, and 15–17**, which depend therefrom, are patentable over Slatkine. In addition, **claims 1 and 14 and claims 2–11, 13, and 15–17**, which depend therefrom, are patentable over the combination of Slatkine and Muller.

CONCLUSION

For the foregoing reasons, it is submitted that the claims of the present application are in condition for allowance. Early notice thereof is respectfully requested.

It is believed that there is no fee associated with the filing and consideration of this amendment. Should the Commissioner decide that any fee or fee deficiency is due, the Commissioner is hereby authorized to charge any and all such fees, and/or credit any overpayments, incurred as a result of entering this amendment to Deposit Account No. 03-0172, Order No. 30276.04004.

Respectfully submitted,

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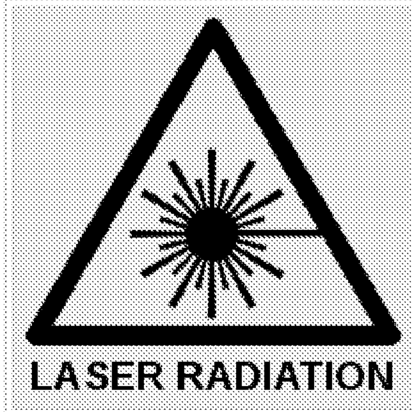
Laser safety

From Wikipedia, the free encyclopedia

Laser safety is safe design, use and implementation of lasers to minimise the risk of laser accidents, especially those involving eye injuries. Since even relatively small amounts of laser light can lead to permanent eye injuries, the sale and usage of lasers is typically subject to government regulations.



A typical laser warning symbol.

Moderate and high-power lasers are potentially hazardous because they can burn the retina of the eye, or even the skin. To control the risk of injury, various specifications, for example ANSI Z136 in the US and IEC 60825 internationally, define "classes" of laser depending on their power and wavelength. These regulations also prescribe required safety measures, such as labeling lasers with specific warnings, and wearing laser safety goggles when operating lasers.

Contents

Laser radiation hazards

Laser radiation predominantly causes injury via thermal effects. Even moderately powered lasers can cause injury to the eye. High power lasers can also burn the skin. Some lasers are so powerful that even the diffuse reflection from a surface can be hazardous to the eye.

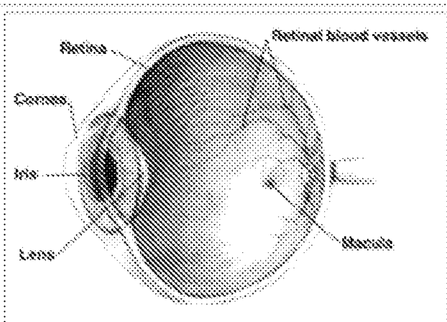


Diagram of a human eye.

The coherence, the low divergence angle of laser light and the focusing mechanism of the eye means that laser light can be concentrated into an extremely small spot on the retina. A transient increase of only 10 °C can destroy retinal photoreceptors. If the laser is sufficiently powerful, permanent damage can occur within a fraction of a second, faster than the blink of an eye. Sufficiently powerful visible to near infrared laser radiation (400-1400 nm) will penetrate the eyeball and may cause heating of the retina, whereas exposure to laser radiation with wavelengths less than 400 nm and greater than 1400 nm are largely absorbed by the cornea and lens, leading to the development of cataracts or burn injuries.[1]

Infrared lasers are particularly hazardous, since the body's protective "blink reflex" response is triggered only by visible light. For example, some people exposed to high power Nd:YAG laser emitting invisible 1064 nm radiation, may not feel pain or notice immediate damage to their eyesight. A pop or click noise emanating from the eyeball may be the only indication that retinal damage has occurred i.e. the retina was heated to over 100 °C resulting in localized explosive boiling accompanied by the immediate creation of a permanent blind spot.[2]

Damage mechanisms

Lasers can cause damage in biological tissues, both to the eye and to the skin, due to several mechanisms. [3] Thermal damage, or burn, occurs when tissues are heated to the point where denaturation of proteins occurs. Another mechanism is photochemical damage, where light triggers chemical reactions in tissue. Photochemical damage occurs mostly with short-wavelength (blue) and ultra-violet light and can be accumulated over the course of hours. Laser pulses shorter than about 1 μs can cause a rapid raise in temperature, resulting in explosive boiling of water. The shock wave from the explosion can subsequently cause damage relatively far away from the point of impact. Ultrashort pulses can also exhibit self-focusing in the transparent parts of the eye, leading to an increase of the damage potential compared to longer pulses with the same energy.

The eye focuses visible and near-infrared light onto the retina. A laser beam can be focused to an intensity on the retina which may be up to 2×10^5 times higher than at the point where the laser beam enters the eye. Most of the light is absorbed by melanin pigments in the pigment epithelium just behind

the photoreceptors,[3] and causes burns in the retina. Ultraviolet light with wavelengths shorter than 400 nm tends to be absorbed in the cornea and lens, where it can produce injuries at relatively low powers due to photochemical damage. Infrared light mainly causes thermal damage to the retina at near-infrared wavelengths and to more frontal parts of the eye at longer wavelengths. The table below summarizes the various medical conditions caused by lasers at different wavelengths, not including injuries due to pulsed lasers.

Wavelength range	pathological effect
180–315 nm (UV-B, UV-C)	photokeratitis (inflammation of the cornea, equivalent to sunburn)
315–400 nm (UV-A)	photochemical cataract (clouding of the eye lens)
400–780 nm (visible)	photochemical damage to the retina, retinal burn
780–1400 nm (near-IR)	cataract, retinal burn
1.4–3.0μm (IR)	aqueous flare (protein in the aqueous humour), cataract, corneal burn
3.0 μm–1 mm	corneal burn

The skin is usually much less sensitive to laser light than the eye, but excessive exposure to ultraviolet light from any source (laser or non-laser) can cause short- and long-term effects similar to sunburn, while visible and infrared wavelengths are mainly harmful due to thermal damage.[3]

Lasers and aviation safety

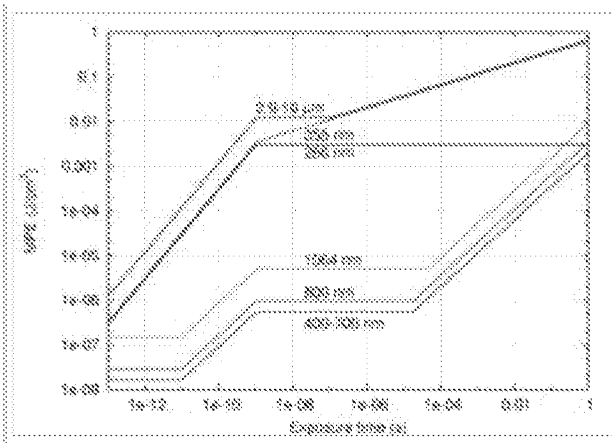
Main article: Lasers and aviation safety

Since November 19, 2004 there have been over 2800 incidents of lasers directed at aircraft within the United States. These concerns have led to an inquiry in the US congress.[4] Exposure to hand-held laser light under such circumstances may seem trivial given the brevity of exposure, the large distances involved and beam spread of up to several metres. However, laser exposure may create dangerous conditions such as flash blindness. If this occurs during a critical moment in aircraft operation, the aircraft may be endangered. In addition, some 18% to 35% of the population possess the autosomal dominant genetic trait, photic sneeze,[5] that causes the affected individual to experience an involuntary sneezing fit when exposed to a sudden flash of light. Some observers believe that the danger is greatly exaggerated, at least for small hand-held lasers.[6]

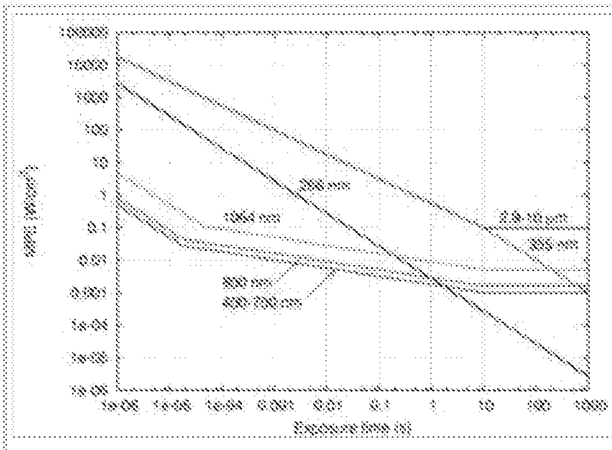
Maximum permissible exposure

The *maximum permissible exposure* (MPE) is the highest power or energy density (in W/cm^2 or J/cm^2) of a light source that is considered safe, i.e. that has a negligible probability for creating a damage. It is usually about 10% of the dose that has a 50% chance of creating damage[7] under worst-case conditions. The MPE is measured at the cornea of the human eye or at the skin, for a given wavelength and exposure time.

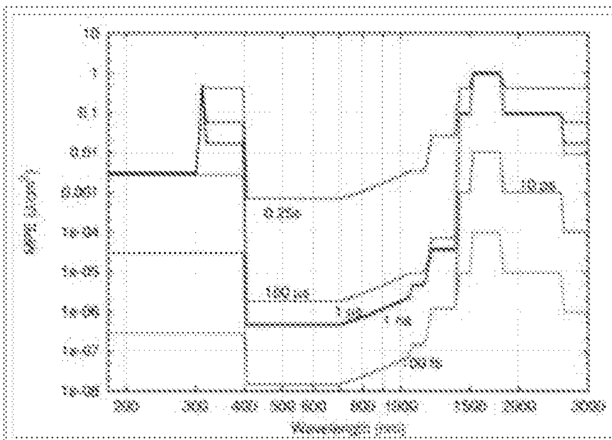
A calculation of the MPE for occular exposure takes into account the various ways light can act upon the eye. For example, deep-ultraviolet light causes accumulating damage, even at very low powers. Infrared light with a wavelength longer than about 1400 nm is absorbed by the transparent parts of the eye before it reaches the retina, which means that the MPE for these wavelengths is higher than for visible light. In addition to the wavelength and exposure time, the MPE takes into account the spatial distribution of the light (from a laser or otherwise). Collimated laser beams of visible and near-infrared light are especially dangerous at relatively low powers because the lens focuses the light onto a tiny spot on the retina. Light sources with a smaller degree of spatial coherence than a well-collimated laser beam lead to a distribution of the light over a larger area on the retina. For such sources, the MPE is higher than for collimated laser beams. In the MPE calculation, the worst-case scenario is assumed, in which the eye lens focuses the light into the smallest possible spot size on the retina for the particular wavelength and the pupil is fully open. Although the MPE is specified as power or energy per unit surface, it is based on the power or energy that can pass through a fully open pupil (0.39 cm^2) for visible and near-infrared wavelengths. This is relevant for laser beams that have a cross-section smaller than 0.39 cm^2. The IEC-60825-1 and ANSI Z136.1 standards include methods of calculating MPEs.[3]



Maximum permissible exposure (MPE) at the cornea for a collimated laser beam according to IEC 60825, as energy density versus exposure time for various wavelengths.



MPE as power density versus exposure time for various wavelengths.



MPE as energy density versus wavelength for various exposure times (pulse durations).

Regulations

In various jurisdictions, standards bodies, legislation, and government regulations define classes of laser according to the risks associated with them, and define required safety measures for people who may be exposed to those lasers.

In the European Community, eye protection requirements are specified in European norm EN 207. In addition to EN 207, European norm EN 208 specifies requirements for

goggles for use during beam alignment.
These transmit a portion of the laser light, permitting the operator to see where the beam is, and do not provide complete protection against a direct laser beam hit. Finally, European norm EN 60825 specifies optical densities in extreme situations.

In the U.S., guidance for the use of protective eyewear, and other elements of safe laser use, is given in the ANSI Z136 series of standards. A full copy of these standards can be obtained via ANSI or the secretariat and publisher of these standards, the Laser Institute of America[8]. The standards are as follows:

- ANSI Z136.1 - Safe Use of Lasers
- ANSI Z136.2 – Safe Use of Lasers in Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources
- ANSI Z136.3 – Safe Use of Lasers in Health Care Facilities
- ANSI Z136.5 – Safe Use of Lasers in Educational Institutions
- ANSI Z136.6 – Safe Use of Lasers Outdoors

The U.S. Food and Drug Administration (FDA) requires all class IIIb and class IV lasers offered in commerce in the US to have five standard safety features: a key switch, a safety interlock dongle, a power indicator, an aperture shutter, and an emission delay (normally two to three seconds). OEM lasers, designed to be parts of other components (such as DVD burners) are exempt from this requirement. Some non-portable lasers may not have a safety dongle or an emission delay, but have an emergency stop button and/or a remote switch.

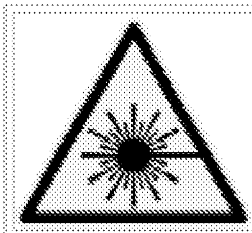
Classification

Lasers have been classified by wavelength and maximum output power into four classes and a few subclasses since the early 1970s. The classifications categorize lasers according to their ability to produce damage in exposed people, from class 1 (no hazard during normal use) to class 4 (severe hazard for eyes and skin). There are two classification systems, the "old system" used before 2002, and the "revised system" being phased in since 2002. The latter reflects the greater knowledge of lasers that has been accumulated since the original classification system was devised, and permits certain types of lasers to be recognized as having a lower hazard than was implied by their placement in the original classification system. The revised system is part of the revised IEC 60825 standard. From 2007, the revised system is also incorporated into the US-oriented ANSI Laser Safety Standard (ANSI Z136.1). Since 2007, labeling according to the revised system is accepted by the U.S. Food and Drug Administration (FDA) on laser products imported into the US. The old and revised systems can be distinguished by the 1M, 2M and 3R classes used only in the revised system and the 2A and 3A classes used only in the old system. Class numbers were designated using Roman numerals (I–IV) in the US under the old system and Arabic numerals (1–4) in the EU. The revised system uses Arabic numerals (1–4) in all jurisdictions.

The classification of a laser is based on the concept of *accessible emission limits* (AEL) that are defined for each laser class. This is usually a maximum power (in W) or energy (in J) that can be emitted in a specified wavelength range and exposure time. For infrared wavelengths above 4 µm, it is specified as a maximum power density (in W/m^2). It is the responsibility of the manufacturer to provide the correct classification of a laser, and to equip the laser with appropriate warning labels and safety measures as prescribed by the regulations. Safety measures used with the more powerful lasers include key-controlled operation, warning lights to indicate laser light emission, a beam stop or attenuator, and an electrical contact that the user can connect to an emergency stop or interlock.

Revised system

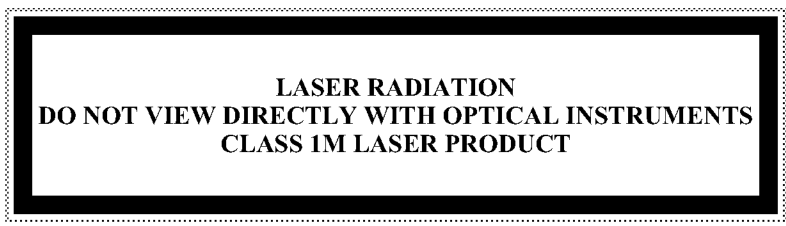
Below, the main characteristics and requirements for the classification system as specified by the IEC 60825-1 standard [3] are listed, along with typical required warning labels. Additionally, classes 2 and higher must have the triangular warning label shown here and other labels are required in specific cases indicating laser emission, laser apertures, skin hazards, and invisible wavelengths.


Warning label for class 2 and higher

Class 1

A class 1 laser is safe under all conditions of normal use. This means the maximum permissible exposure (MPE) cannot be exceeded. This class includes high-power lasers within an enclosure that prevents exposure to the radiation and that cannot be opened without shutting down the laser. For example, a continuous laser at 600 nm can emit up to 0.39 mW, but for shorter wavelengths, the maximum emission is lower because of the potential of those wavelengths to generate photochemical damage. The maximum emission is also related to the pulse duration in the case of pulsed lasers and the degree of spatial coherence.

Class 1M



A Class 1M laser is safe for all conditions of use except when passed through magnifying optics such as microscopes and telescopes. Class 1M lasers produce large-diameter beams, or beams that are divergent. The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam. If the beam is refocused, the hazard of Class 1M lasers may be increased and the product class may be changed. A laser can be classified as Class 1M if the total output power is below class 3B but the power that can pass through the pupil of the eye is within Class 1.

Class 2

A Class 2 laser is safe because the blink reflex will limit the exposure to no more than 0.25 seconds. It only applies to visible-light lasers (400–700 nm). Class-2 lasers are limited to 1 mW continuous wave, or more if the emission time is less than 0.25 seconds or if the light is not spatially coherent. Intentional suppression of the blink reflex could lead to eye injury. Many laser pointers are class 2.

Class 2M

A Class 2M laser is safe because of the blink reflex if not viewed through optical instruments. As with class 1M, this applies to laser beams with a large diameter or large divergence, for which the amount of light passing through the pupil cannot exceed the limits for class 2.

Class 3R

A Class 3R laser is considered safe if handled carefully, with restricted beam viewing. With a class 3R laser, the MPE can be exceeded, but with a low risk of injury. Visible continuous lasers in Class 3R are limited to 5 mW. For other wavelengths and for pulsed lasers, other limits apply.

LASER RADIATION
AVOID DIRECT EYE EXPOSURE
CLASS 3R LASER PRODUCT

Class 3B

A Class 3B laser is hazardous if the eye is exposed directly, but diffuse reflections such as from paper or other matte surfaces are not harmful. Continuous lasers in the wavelength range from 315 nm to far infrared are limited to 0.5 W. For pulsed lasers between 400 and 700 nm, the limit is 30 mJ. Other limits apply to other wavelengths and to ultrashort pulsed lasers. Protective eyewear is typically required where direct viewing of a class 3B laser beam may occur. Class-3B lasers must be equipped with a key switch and a safety interlock.

LASER RADIATION
AVOID EXPOSURE TO THE BEAM
CLASS 3B LASER PRODUCT

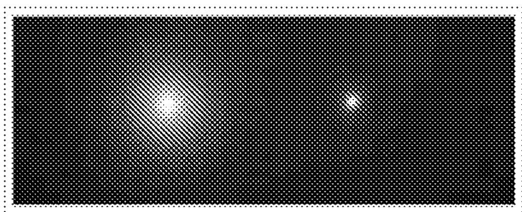
Class 4

Class 4 lasers include all lasers with beam power greater than class 3B. By definition, a class-4 laser can burn the skin, in addition to potentially devastating and permanent eye damage as a result of direct or diffuse beam viewing. These lasers may ignite combustible materials, and thus may represent a fire risk. Class 4 lasers must be equipped with a key switch and a safety interlock. Many industrial, scientific, military, and medical lasers are in this category.

LASER RADIATION
AVOID EYE OR SKIN EXPOSURE TO
DIRECT OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

Old system

The safety classes in the "old system" of classification were established in the United States through consensus standards (ANSI Z136.1) and Federal and state regulations. The international classification described in consensus standards such as IEC 825 (later IEC 60825) was based on the same concepts but presented with designations slightly different from the US classification.



Green laser – class IIIb compared to class IIIa

This classification system is only slightly altered from the original system developed in the early 1970s. It is still used by US laser product safety regulations. The laser powers mentioned are typical values. Classification is also dependent on the wavelength and on whether the laser is pulsed or continuous.

Class I

Inherently safe; no possibility of eye damage. This can be either because of a low output power (in which case eye damage is impossible even after hours of exposure), or due to an enclosure preventing user access to the laser beam during normal operation, such as in CD players or laser printers.

Class II

The blink reflex of the human eye (aversion response) will prevent eye damage, unless the person deliberately stares into the beam for an extended period. Output power may be up to 1 mW. This class includes only lasers that emit visible light. Some laser pointers are in this category.

Class IIa

A region in the low-power end of Class II where the laser requires in excess of 1000 seconds of continuous viewing to produce a burn to the retina. Supermarket laser scanners are in this subclass.

Class IIIa

Lasers in this class are mostly dangerous in combination *with* optical instruments which change the beam diameter or power density. Output power does not exceed 5 mW. Beam power density may not exceed 2.5 mW/square cm. Many laser sights for firearms and laser pointers are in this category.

Class IIIb

Lasers in this class may cause damage if the beam enters the eye directly. This generally applies to lasers powered from 5–500 mW. Lasers in this category can cause permanent eye damage with exposures of 1/100th of a second or less depending on the strength of the laser. A diffuse reflection is generally not hazardous but specular reflections can be just as dangerous as direct exposures. Protective eyewear is recommended when direct beam viewing of Class IIIb lasers may occur. Lasers at the high power end of this class may also present a fire hazard and can lightly burn skin.

Class IV

Lasers in this class have output powers of more than 500 mW in the beam and may cause severe, permanent damage to eye or skin without being magnified by optics of eye or instrumentation. Diffuse reflections of the laser beam can be hazardous to skin or eye within the Nominal Hazard Zone. Many industrial, scientific, military, and medical lasers are in this category.

Safety measures

General precautions

Many scientists involved with lasers agree on the following guidelines:[9][10][11][12][13]

- Everyone who uses a laser should be aware of the risks. This awareness is not just a matter of time spent with lasers; to the contrary, long-term dealing with invisible risks (such as from infrared laser beams) tends to reduce risk awareness, rather than to sharpen it.

- Optical experiments should be carried out on an optical table with all laser beams travelling in the horizontal plane only, and all beams should be stopped at the edges of the table. Users should never put their eyes at the level of the horizontal plane where the beams are in case of reflected beams that leave the table.

- Watches and other jewelry that might enter the optical plane should not be allowed in the laboratory. All non-optical objects that are close to the optical plane should have a matte finish in order to prevent specular reflections.

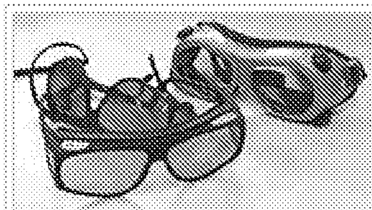
- Adequate eye protection should always be required for everyone in the room if there is a significant risk for eye injury.

- High-intensity beams that can cause fire or skin damage (mainly from class 4 and ultraviolet lasers) and that are not frequently modified should be guided through tubes.

- Alignment of beams and optical components should be performed at a reduced beam power whenever possible.

Protective eyewear

The use of eye protection when operating lasers of classes 3B and 4 in a manner that may result in eye exposure in excess of the MPE is strongly recommended, and is required in the workplace by the U.S. Occupational Safety and Health Administration.


Laser goggles

Protective eyewear in the form of spectacles or goggles with appropriately filtering optics can protect the eyes from the reflected or scattered laser light with a hazardous beam power, as well as from direct exposure to a laser beam. Eyewear must be selected for the specific type of laser, to block or attenuate in the appropriate wavelength range. For example, eyewear absorbing 532 nm typically has an orange appearance, transmitting wavelengths larger than 550 nm. Such eyewear would be useless as protection against a laser emitting at 800 nm. Eyewear is rated for optical density (OD), which is the base-10 logarithm of the attenuation factor by which the optical filter reduces beam power. For example, eyewear with OD 3 will reduce the beam power in the specified wavelength range by a factor of 1,000. In addition to an optical density sufficient to reduce beam power to below the maximum permissible exposure (see above), laser eyewear used where direct beam exposure is possible should be able to withstand a direct hit from the laser beam without breaking. The protective specifications (wavelengths and optical densities) are usually printed on the goggles, generally near the top of the unit. In the European Community, manufacturers are required by European norm EN 207 to specify the maximum power rating rather than the optical density.

Interlocks and automatic shutdown

Interlocks are circuits that shut down a laser if some condition is not met, such as if the laser casing or a room door is open. Class 3B and 4 lasers typically provide a connection for an external interlock circuit. Lasers that are class 1 only because the light is contained within an enclosure nearly always have an interlock that disables the laser if that enclosure is opened.

Some systems have electronics that automatically shut down the laser under other conditions. For example, some fiber optic communication systems have circuits that automatically shut down

transmission if a fiber is disconnected or broken, to ensure safety of technicians during system maintenance.[14][15]

Laser safety officer

In many jurisdictions, organizations that operate lasers are required to appoint a laser safety officer (LSO). The LSO is responsible for ensuring that safety regulations are followed by all other workers in the organization.

Laser safety in research environments

It is common in research in both university and industrial laboratories for operators to violate safety regulations and remove their eye protection during certain procedures, or even to avoid wearing it altogether. Some find the use of safety glasses over a long time to be uncomfortable, and in many types of optical experiments it is also inconvenient. For example in spectroscopy, the experimental arrangement is constantly being modified and fine-tuned. This requires knowledge of beam location, which is often most simply achieved with the naked eye, although other, often less accurate, detection methods are available. In this situation, many scientists assign a higher priority to convenience and comfort than to safety and regulatory compliance, and routinely breach the laser safety regulations. Sometimes it is perceived as unavoidable when working with, for example, an RGB laser, which would require very careful selection of the Optical Density of protective eyewear or the use of completely black goggles.

Eye protection is often considered uncomfortable because of both reduced vision and physical discomfort. Especially for goggles that protect against visible-light wavelengths, color vision is impaired, which means that it becomes hard to see green or red indicator lights on equipment and to recognize tools. Moreover, many types of goggles transmit less than 30 percent of visible light,[16] which means that standard work environment lighting levels may be inadequate, leading to increased risks for other accidents, such as tripping over cables. Finally, the weight, fit, and ventilation may cause physical discomfort.

When eye protection is neglected, scientists attempt to minimize risks by other means, such as keeping all beams within a restricted horizontal space, and removing jewelry. However, the reduced safety measures commonplace in scientific environments cannot completely prevent accidents. It is not uncommon for someone who did several years of laser-related research to have experienced an accident that resulted in a small, but permanent eye injury, typically a blind spot somewhere in the peripheral vision.

Experimentalists often feel that safety eyewear is not necessary when dealing with an experiment carried out within the horizontal plane. However, in a non-trivial optical setup, it is very hard to ensure that all mirrors, filters, and lenses are strictly kept in a vertical position at all times, particularly when the setup is constantly modified, and that metallic tools such as screwdrivers also can redirect a beam. Stray reflections are usually unnoticed until an accident occurs. Since nobody can guarantee that all these hazards can be safely avoided without wearing safety eyewear, when infrared laser beams with non-negligible powers are used, working without safety eyewear is not permitted by any official safety regulations.

Laser pointers

Main article: Laser pointer

In the period from 2000 to 2008, increasing attention has been paid to the risks posed by so called laser pointers and laser pens. Typically, sales of laser pointers is restricted to either class 3A (<5 mW) or class 2 (<1 mW), depending on local regulations. For example, in the US, class 3A is the maximum permitted, unless a key actuated control or other safety features are provided[17] and in the UK and Australia, class 2 is the maximum allowed class. However, because enforcement is often not very strict, class 3A laser pointers are often available for sale even in countries where they are not allowed.

Van Norren et al. (1998)[18] could not find a single example in the medical literature of a <1 mW class II laser causing eyesight damage. Mainster et al. (2003)[19] provide one case, an 11 year old child who temporarily damaged her eyesight by holding an approximately 5 mW red laser pointer close to the eye and staring into the beam for 10 seconds, she experienced scotoma (a blind spot) but fully recovered after 3 months. Luttrulla & Hallisey (1999) describe a similar case, a 34 year old male who stared into the beam of a class IIIa red laser for 30 to 60 seconds, causing temporary central scotoma and visual field loss. His eyesight fully recovered within 2 days, at the time of his eye exam. An intravenous fundus fluorescein angiogram, a technique used by ophthalmologists to visualise the retina of the eye in fine detail, identified subtle discoloration of the fovea.

Thus, it appears that a brief 0.25-second exposure to a <5 mW laser such as found in red laser pointers does not pose a threat to eye health. On the other hand there is a potential for injury if a person deliberately stares into a beam of a class IIIa laser for few seconds or more at close range. Even if injury occurs, most people will fully recover their vision. Further experienced discomforts than these may be psychological rather than physical. With regard to green laser pointers the safe exposure time may be less, and with even higher powered lasers instant permanent damage should be expected. These conclusions must be qualified with recent theoretical observations that certain prescription medications may interact with some wavelengths of laser light, causing increased sensitivity (phototoxicity).

Beyond the question of physical injury to the eye from a laser pointer, several other undesirable effects are possible. These include short-lived flash blindness if the beam is encountered in darkened surroundings, as when driving at night. This may result in momentary loss of vehicular control. Lasers pointed at aircraft are a hazard to aviation. A police officer seeing a red dot on his chest may conclude that a sniper is targeting him and take aggressive action. [20] In addition, the startle reflex exhibited by some exposed unexpectedly to laser light of this sort has been reported to have resulted in cases of self-injury or loss of control. For these and similar reasons, the US Food and Drug Administration has advised that laser pointers are not toys and should not be used by minors except under the direct supervision of an adult.

Non-beam hazards – electrical and other

A discussion of laser safety would not be complete without mention of non-beam hazards that are often associated with use of laser systems. Many lasers are high voltage devices, typically 400 V upward for a small 5 mJ pulsed laser, and exceeding many kilovolts in higher powered lasers. This, coupled with high pressure water for cooling the laser and other associated electrical equipment can create a greater hazard than the laser beam itself.

Electric equipment should generally be installed at least 250 mm / 10 inches above the floor to reduce electric risk in the case of flooding. Optical tables, lasers, and other equipment should be well grounded. Enclosure interlocks should be respected and special precautions taken during troubleshooting.

In addition to the electrical hazards, lasers may create chemical, mechanical, and other hazards specific to particular installations. Chemical hazards may include materials intrinsic to the laser, such as beryllium oxide in argon ion laser tubes, halogens in excimer lasers, organic dyes dissolved in toxic or flammable solvents in dye lasers, and heavy metal vapors and asbestos insulation in helium cadmium lasers. They may also include materials released during laser processing, such as metal fumes from cutting or surface treatments of metals or the complex mix of decomposition products produced in the high energy plasma of a laser cutting plastics.

Mechanical hazards may include moving parts in vacuum and pressure pumps; implosion or explosion of flashlamps, plasma tubes, water jackets, and gas handling equipment.

High temperatures and fire hazards may also result from the operation of high-powered Class IIIB or any Class IV Laser.

In commercial laser systems, hazard mitigations such as the presence of fusible plugs, thermal interrupters, and pressure relief valves reduce the hazard of, for example, a steam explosion arising from an obstructed water cooling jacket. Interlocks, shutters, and warning lights are often critical elements of modern commercial installations. In older lasers, experimental and hobby systems, and those removed from other equipment (OEM units) special care must be taken to anticipate and reduce the consequences of misuse as well as various failure modes.

See also

- Lasers and aviation safety
- Audience scanning – use of lasers in light shows, where they are deliberately directed into the audience to create special effects

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External links

- Laser Safety Officer
- Laser safety fact sheet (University of Kentucky)
- U.S. Navy Laser Safety Website
- OSHA Technical Manual Section III, Chapter 6, Laser Safety
- Laser safety resources (Vanderbilt Environmental Health & Safety)
- OSHA Web Page on Laser Hazards
- Laser Institute of America - Secretariat and Publisher of the ANSI Z136 Series of Laser Safety Standards